RADIO EMISSION FROM THE VELA–PUPPIS REGION

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Summary

The Vela-Puppis region has been surveyed with Mills Cross radio telescopes, and radio isophotes plotted at two wavelengths. Many discrete sources have been observed. Several H II regions have been detected in emission at 3·5 m and in absorption at 15·2 m; the radiation from such objects is of thermal origin. The outstanding feature of this region is a group of strong non-thermal sources near the galactic equator. These are superimposed on an intense belt of radiation along the equator, and this, too, is certainly non-thermal in origin. Some correlation with galactic structure is suggested.

I. Introduction

The constellations of Vela and Puppis contain some of the brightest emission regions in the southern Milky Way. The most extensive H II region known lies in this area; it is excited by the early-type stars γ Velorum and ζ Puppis, and its fragments are scattered over several hundred square degrees of sky (Gum 1955, 1956). The present paper describes general surveys of the Vela-Puppis region at two radio wavelengths. These surveys have shown that some parts of this H II region can be detected in emission or absorption, depending on the wavelength used, but they have also revealed a compact group of non-thermal sources near the galactic equator, and the characteristics of these sources are studied in some detail.

The instruments used were the two Mills Cross radio telescopes at the Fleurs Field Station, near Sydney, N.S.W. (151 °E., 34 °S.). In each system the outputs of two long mutually perpendicular arrays are combined in a phase-switching receiver to give a narrow primary beam which can be pointed to any direction in the meridian by altering the phasing of the dipoles in the north-south array. In normal use the beam is not swung more than about 45° from the zenith. The aerial beams are circular and of Gaussian cross section, with half-power widths 0°·8 and 1°·4 at 3·5 and 15·2 m respectively for observations not far from the zenith. The aerial systems and their associated equipment are described in separate papers (Mills *et al.* 1958; Shain 1958).

II. Observations and Results

(*a*) *Observations at 3·5 m*

A complete set of records covering the sky bounded by R.A. 0600 and 1000, Dec. −34° and −57°, was used. These records are of the " scanning " type previously described (Mills and Slee 1957) in which five neighbouring

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declinations are surveyed quasi-simultaneously; the north-south aerial of the cross is switched to each declination for 12 sec in every minute. The interval between these positions is about 20′, and the subsequent record is taken with the central declination displaced about 1° 20′ from its predecessor; the most northerly scan of one record (known as E) thus coincides with the most southerly or A-scan of the next.

For the region of the sky given above, the values of equivalent aerial temperature T_a were plotted on a grid in galactic coordinates, points being taken on each scan at intervals of 2^m in Right Ascension (1^m in regions of special interest). The A-scan of each record was combined with the E-scan of the next, and, where a strong north-south gradient of aerial temperature occurs, as in low galactic latitudes, small corrections for beam asymmetry were applied to the B and D positions. The values of T_a were plotted to the nearest 50 °K—this representing the fluctuation level of the records—and contours drawn at intervals of 250 or 500 °K. The resulting map is shown in Figure 1; closed contours around sources of small angular extent have been omitted.

(b) *Observations at 15·2 m*

The operation of the long-wavelength cross is curtailed by the ionosphere by day and by interference from broadcasting stations at night. During November and December 1956, when the majority of the observations were taken, records of reasonable quality could only be obtained between about 0200 and 0600 hr, local time, using a bandwidth of 10 kc/s. The use of the aerial for other purposes precluded observation before about 0715 sidereal time, so the preceding parts of the principal Vela-Puppis H II region were missed; otherwise a reasonable coverage of the area between Dec. −39° and −52° was achieved, with the aid of a few records taken in November 1957 to fill in some of the missing portions. Values of T_a were plotted at intervals of 3^m in Right Ascension, and a chart of the region in galactic coordinates derived (Fig. 2), with contours at intervals of 30,000 °K.

Observations at this long wavelength are subject to errors due to ionospheric refraction. Besides the expected refraction for a spherical ionosphere, routine observations of intense discrete sources show northward displacements of the order of 1°, due to the prismatic effect of the north-south gradient of total F-region ionization (Shain, personal communication). As all the records were taken at about the same season and time of day, a uniform correction in declination of $\frac{1}{2}°$ has been applied to the whole chart; this is consistent with the observed position of the source Puppis-A.

(c) *Discrete Sources*

A search for discrete sources was made on each of the two grid plots of equivalent aerial temperature. When the possible features appearing on at least two adjacent scans had been listed, they were checked on the tracings of records from which the grid plots had been derived, and about half on each list rejected. Special attention was paid to positions in which side-lobe effects of intense sources might be expected to occur, and objects in such locations were

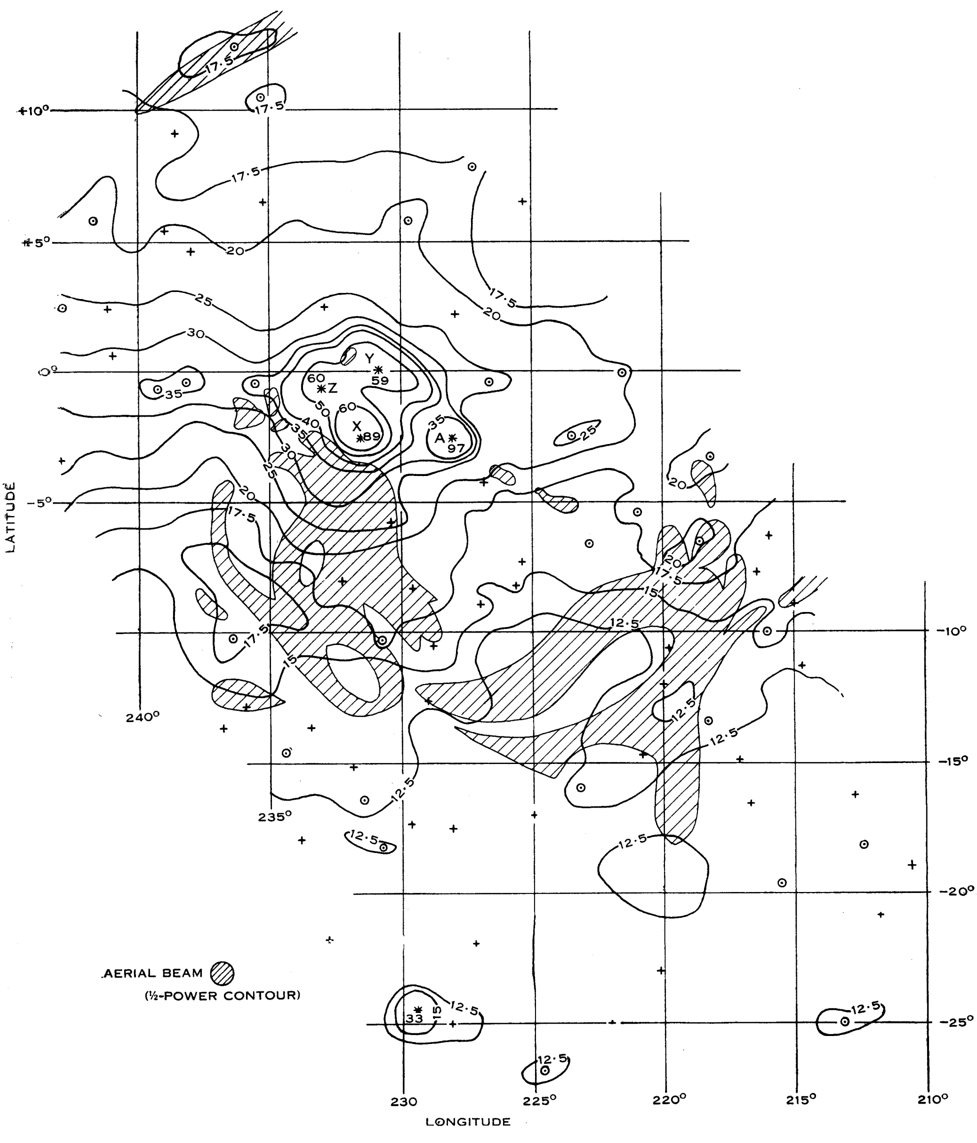

Fig. 1.—Contours of equivalent aerial temperature at 3·5 m wavelength. The unit is 100 °K, and the half-power contour of the aerial is shown in the bottom left-hand corner. The shaded areas show the extent of H II emission from the large, nearby H II region Stromlo 12 (after Gum 1956). The positions of discrete sources are also indicated on the figure. Sources of small angular size are indicated by crosses (+) and those with angular sizes comparable to the aerial beamwidth by circled points (⊙). Very closely spaced contours around the most intense sources have been omitted, the peak temperature only being given. The sources Puppis-A, Vela-X, Vela-Y, and Vela-Z are distinguished by the letters A, X, Y, and Z respectively.

retained only after severe scrutiny of the tracings. Finally, the positions and intensities of the remaining sources included in the list were measured from the tracings.

In Appendix I, Table 1 lists 77 sources observed at 3·5 m.* Each source is assigned a serial number with prefix R, and a reference indicating galactic position, to the nearest degree, is also shown. The third and fourth columns give the

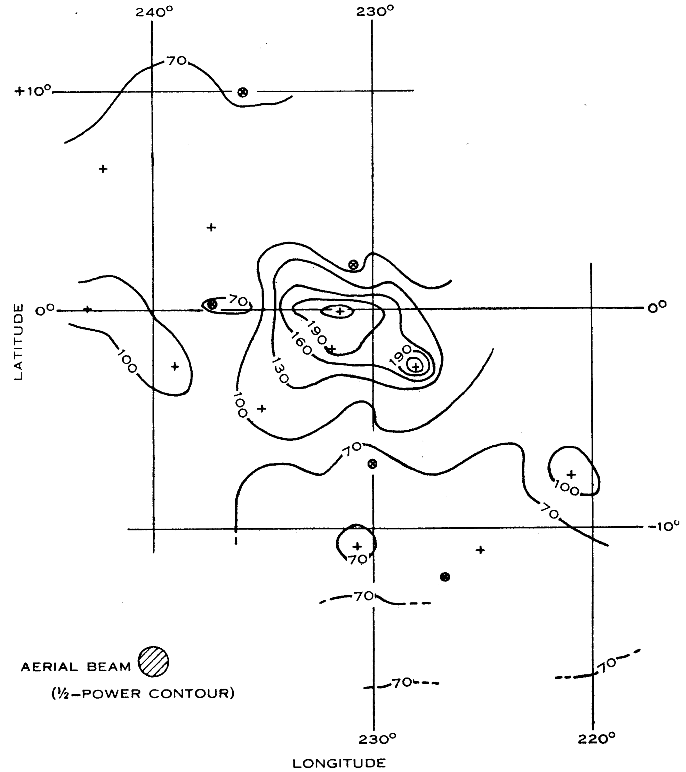

Fig. 2.—Contours of equivalent aerial temperature at 15·2 m wavelength. The unit is 1000 °K, and the half-power contour of the aerial beam is shown. Discrete sources (+) and localized minima due to absorption (⊗) are indicated.

Right Ascension and declination at epoch 1950. The accuracy of the estimated positions varies from source to source. For the strongest, clearly defined sources the probable errors are estimated to be about $0^m{\cdot}3$ in Right Ascension and 3′ in declination. The uncertainty is increased for the weaker sources ($0^m{\cdot}5$ and 10′), whilst the probable errors may be up to $1^m{\cdot}0$ and 20′ for very extended, or possibly confused, objects. The fifth column shows ΔT_a, the increase in equivalent temperature due to the source, and for sources which do not appear

* A definitive catalogue of discrete sources observed with the 3·5 m Cross is being prepared by Mills and his collaborators, and this catalogue will, in due course, include the Vela-Puppis region.

to be appreciably extended the corresponding flux density S is given in units of 10^{-26} W m^{-2} (c/s)$^{-1}$. For a few bright extended sources, an integrated flux density has been estimated and inserted in column 6 in italics. In the final column, a bracketed reference to a strong source, e.g. (Hya-A), indicates a possibility of interference from that source; although, as mentioned before, most of the objects of which the reality is doubtful have been omitted from the list. Also in this column are references to previous source surveys and possible identifications with optical objects, the more doubtful identifications being indicated again by brackets.

Observations at 15·2 m show localized minima as well as maxima, and Table 2 gives details of the 16 discrete features observed at this wavelength. These are allotted three-figure serial numbers, with the localized minima, or negative sources, numbered in italics. These are included only if the absorption is sufficiently great to produce actual minima in T_a; in fact absorption might be expected to occur over considerable areas of the sky. Owing to ionospheric refraction and the poorer signal-to-noise ratio at this wavelength, the quoted positions of the sources in Table 2 are less accurate than those in Table 1. The probable error in Right Ascension is at least 1^m for the brightest sources and 2^m for the others. The declinations of all objects have been shifted, as described in Section II (*b*), and the probable errors in this coordinate are from $\frac{1}{3}°$ for the brightest up to 1° for the fainter or extended objects. ΔT_a is given in units of 1000 °K, and the corresponding peak flux densities in units of 10^{-26} W m^{-2} (c/s)$^{-1}$; no attempt has been made to derive integrated flux densities. Possible correlations with Table 1 and with optical objects are indicated.

III. Theory of H II Region Observations

According to standard theory (Piddington 1951; Mills, Little, and Sheridan 1956) the optical depth τ of a cloud of ionized gas radiating thermally is proportional to the integral along the line of sight of the square of the electron density N_e; this integral is known as the emission measure (E) and its units are pc-cm^{-6}. For an electron temperature T_e of 10^4 °K, the relationships between E and τ are given by

$$\left.\begin{aligned} E&=1\cdot6\times10^4\tau \quad (3\cdot5 \text{ m}),\\ E&=8\times10^2\tau \quad (15 \text{ m}).\end{aligned}\right\} \qquad (1)$$

If an H II region is in front of a uniform background of brightness temperature T_b, its apparent excess temperature is

$$\Delta T=(T_e-T_b)(1-e^{-\tau}), \qquad (2)$$

and it appears in emission if $T_e>T_b$ and in absorption if $T_e<T_b$. For an optically thin region $\tau\ll1$ and

$$\Delta T\simeq(T_e-T_b)\tau.$$

This approximation holds at 3·5 m for the H II regions to be considered in the Vela-Puppis region. Here, T_b is of the order of 2×10^3 °K, and thus, for $T_e=10^4$ °K, the object is seen in emission with

$$E=2\cdot0\Delta T \quad (3\cdot5 \text{ m}). \qquad (3)$$

This relation is not sensitive to changes in T_e or T_b. The constant on the right-hand side is proportional to $T_e^{3/2}.(T_e-T_b)^{-1}$, so that, for the conditions just stated an increase of 20 per cent. in T_e changes the constant in equation (**3**) by only 5 per cent.

At 15 m T_b is of the order of 10^5 °K and the nebula is seen in absorption ($\Delta T<0$). If the region is optically thin the relation corresponding to (**3**) above is

$$E\simeq 10^{-2}\Delta T \quad (15\text{ m}), \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

but the opacity of all but the faintest H II regions detectable optically ($EM\simeq 300$) is too great for this formula to be valid. In this case equation (**2**) must be used without approximation.

In general, the observed change in equivalent temperature, ΔT_a, will not be equal to ΔT, since there is some emission from the space between the H II region and the observer. The value of T_b refers only to the part of the received noise which has been generated behind the H II region. In the case of the H II regions considered here and for the 3·5 m observations, the small corrections required in the calculation of emission measures are negligible. On the other hand, for the 15 m observations the effect of emission from in front of the H II region cannot be ignored, as will be clear from a particular example discussed in Section IV.

Furthermore, the theory given above refers only to H II regions whose angular sizes exceed the aerial beamwidth. In other cases $\Delta T_a<\Delta T$ and the ratio of the quantities can usually be estimated only roughly. For objects of small angular size an integrated emission can be derived from the radio flux density, using the relations

$$S=2k\lambda^{-2}\int\Delta T\mathrm{d}\Omega\propto\int E\mathrm{d}\Omega, \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

provided $\tau\ll 1$. λ and k are the radio wavelength and Boltzmann's constant respectively and $\mathrm{d}\Omega$ is an element of solid angle.

IV. Discussion

(*a*) *H II Regions*

A sketch of the principal H II regions in Vela-Puppis has been given by Gum (1955, 1956) and the relevant part has been reproduced in Figure 3. Apart from a few compact nebulosities near the galactic plane, all the emission objects belong to the vast complex excited by the stars γ Velorum and ζ Puppis, assigned the number 12 in the Mount Stromlo catalogue (Gum 1955) and at a distance from the Sun of about 250 pc. The parts of Stromlo 12 in the field of the present observations have been sketched in Figure 1. Certain sections of the H II region can definitely be associated with features of the radio contours.

The principal part of the nebula surrounds γ Velorum at $l=230°$, $b=-7°$. This is clearly visible on the 3·5 m isophotes as a spur, several degrees wide, extending southwards from the belt of emission along the galactic equator. The excess equivalent aerial temperature at the centre of this object is about 500 °K, and its integrated flux density of the order of 500×10^{-26} m.k.s. units; an accurate determination is hindered by the proximity of the intense extended source Vela-X, which is considered to be unrelated to the H II region. This H II region is of large angular size, and so, by Section III, the emission measure is $2 \times \Delta T_a$ or 1000; rather less than the 3000 estimated optically by Gum for the brighter parts. The difference may be partly due to the "patchiness" visible in photographs of the nebula, since the optical figure refers to the brightest portions, the radio measurement to a smoothed average.

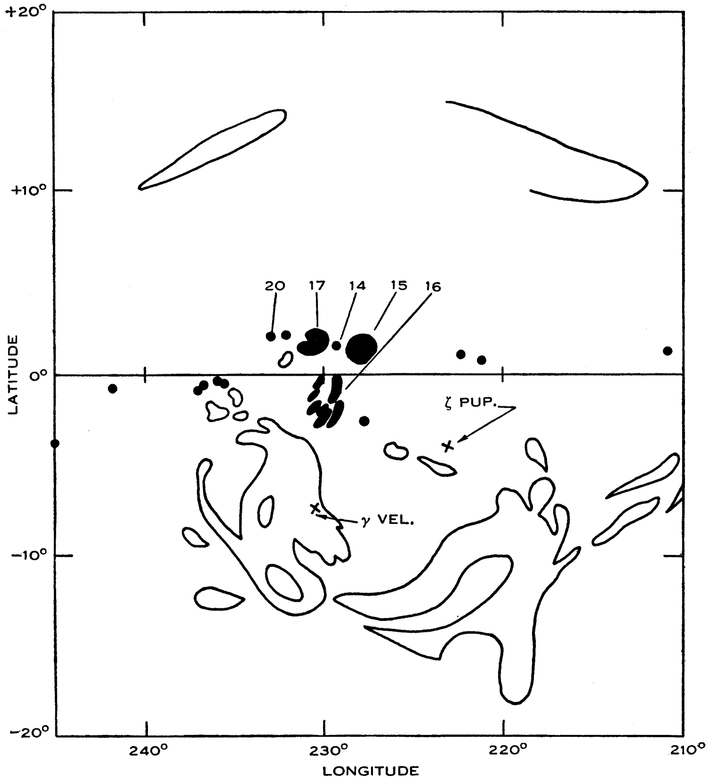

Fig. 3.—Sketch of H II regions (after Gum 1956). The large, unshaded regions are the several parts of Stromlo 12. The other H II regions referred to in the text (Stromlo 14, 15, 16, 17, and 20) are indicated by their numbers.

At 15 m a large area of absorption agrees well in position with the H II region. At the deepest point, listed in Table 2 as *R 104*, the absorption is about 60 per cent., consistent with $\tau=1$ or $E \approx 800$ by equation (**2**), but the optical emission measure of 3000 suggests that the region should absorb 98 per cent. of the background 15 m radiation. The excess of T_a over the electron temperature, about 25,000 °K, would then have to be ascribed to radiation originating between the nebula and the Sun.

The other principal section of the H II region, near $l=220°$, $b=-10°$, is not plainly visible at 3·5 m; it lies in an area of pronounced gradient of brightness temperature. A value $\Delta T_a \simeq 200$ °K can tentatively be assigned, leading to a value of $E \approx 400$. The form of the contours suggests that the ridge of emission just to the north, listed as source R 34, may be associated with the nebula (its neighbourhood seems somewhat obscured optically). At 15 m there is clear evidence of absorption of at least 30 per cent. around longitude 220°, extending from $b=-9°$ to $b=-16°$: this information is gained from a recent record commencing at −18°. *R 100* is another piece of the H II region. The extensive 15 m source R 102, which may be a blend of three distinct peaks of brightness, could hardly be seen through a moderately intense H II region, and so would either lie in front of the latter or be seen through a " window "; it might well be the 3·5 m source R 34, which would thus be non-thermal in character. The same applies to R 103, which lies on the boundary of the H II region at 231°, −11° and which may be identical with R 44.

Some other fragments of the nebula Stromlo 12 can be found on the radio isophotes. The arm at 235°, −8° appears at 3·5 m ($E=400$), although it is merged with another, probably unconnected, object—the source R 52—and there is a suggestion of its presence at 15 m. The outlying portion Stromlo 12b is identified with the extended object R 76 ($E=600$) and may be present at 15 m. A patch of emission at 218°, +12° is outside the area covered by the isophotes, but examination of records of the neighbourhood showed the presence of weak 3·5 m emission, with $E \simeq 250$.

So far, the emphasis has been on searching the radio isophotes for features which correspond to definite patches of optical H II emission. However, there are not only patches of emission which have no marked effects on the isophotes (for example, near 225°, −12°) but also radio features where no H II emission has been observed optically (for example, the well-marked absorption at 15 m, *R 114*, which coincides with an extended 3·5 m source, R 73, at 235°, +10°). These apparent inconsistencies are probably associated with the effects of interstellar absorption on the optical observations.

The possibility of observing, at radio wavelengths, an optically obscured H II region is obvious. For the rest, it should be remembered that in the above discussion only the well-marked radio features have been considered. It is possible that H II emission actually exists over a considerable area of sky in this region, so that some part of the radiation attributed to the background is, in fact, due to the extended H II region. This would explain to some extent the comparatively low values of emission measure deduced from the 3·5 m observations, since the values quoted would correspond to the excess of the brighter features over the H II background.

Quite distinct from the large Stromlo 12, a number of smaller H II regions lie near sources listed in Tables 1 and 2.

Stromlo 14 (227°·9, +1°·4)

This object is of appreciable angular diameter (100′), but it is listed as " very faint " by Gum. The 3·5 m source R 57 lies within a degree of its centre, and if the identification is accepted the emission measure is about 500. There is a trace of absorption at 15 m, although this is not included in Table 2.

Stromlo 15 (229°·2, +1°·6)

Although " moderately bright ", the small diameter (20′) of this nebula would make it a faint object at 3·5 m. It does, however, coincide with a small spur on the contour map, and with ΔT_a=100 °K, as is possible, E could be as high as 2000.

Stromlo 17 (230°·6, +1°·9)

This nebula, being " moderately bright " and 100 by 65′ in size, might be thought to offer a good chance for detection. Unfortunately, its situation on the flank of an intense non-thermal source renders it quite invisible at 3·5 m. At 15 m, *R 109* agrees in position with this nebula ; the observed absorption of about 20 per cent. implies an emission measure greater than 600, the actual value depending on the amount of foreground emission.

Stromlo 20 (232°·9, +2°·1)

This H II region lies within ½° of the source R 62, but an identification is most unlikely. In the first place, the position of the source has a probable error of only about 0°·1, and in any case, the small diameter (7′) of the H II region means that it would be invisible at 3·5 or 15 m unless it were exceedingly bright, or unless the radio emission were non-thermal.

From the results presented above, particularly the study of Stromlo 12, it is clear that, although the values of emission measure deduced from the radio observations are rather low, the radio emission from the H II regions can be adequately accounted for in terms of thermal emission and absorption.

(*b*) *Non-thermal Emission and the Galactic Background*

The most conspicuous radio features of the Vela-Puppis region are the intense extended sources in the galactic plane. Three peaks are much more intense than the others and form a close group (R 56, R 58, and R 59, designated Vela-X, -Y, and -Z respectively). They are not far from the well-known source Puppis-A, which, together with the others, is indicated in Figure 1. At 15 m Vela-Y and -Z are not separated and only two peaks are listed in Table 2 (R 107 and R 108). Their non-thermal nature is shown by the very high equivalent aerial temperatures—more than 200,000 °K—recorded at 15 m. Away from these peaks, the brightness temperature along the equator is about 100,000 °K at 15 m, 3000 °K at 3·5 m, and (from Piddington and Trent 1956*b*) about 15 °K at 0·5 m ; that is, roughly proportional to the 5/2 power of the wavelength. The half-intensity width of the equatorial emission is about 6°, but comparison of the isophotes at the three wavelengths suggests that this width decreases slightly with increasing wavelength.

The 3·5 m contours show a line of extended sources along the galactic plane. Vela-Y and -Z lie in the direction of the Vela dark nebula (Greenstein 1937), and may represent regions of interaction between interstellar dust, fast particles, and magnetic fields, in accordance with current theories of non-thermal radio emission. The other sources along the equator may be similar objects.

Apart from these sources, there is a gradual increase of 3·5 m brightness temperature along the galactic equator from longitude 220 to 240°. A similar effect, complicated by equatorial absorption (*R 111*) between 235 and 240°, occurs at 15 m and this may be related to the spiral structure of the Galaxy. Vela-Puppis lies about 90° from the galactic centre and the path length through the local arm which is included in the line of sight increases with increasing longitude (see, for example, Fig. 1 of Kerr, Hindman, and Carpenter 1957). If the emitting regions are optically thin, then the brightness temperatures depend on the total depth of the emitting material in the line of sight, so that, at least in this limited region of the Galaxy, the metre wavelength observations are consistent with the origin of non-thermal radiation within spiral arms.

It is of interest to note that the 3·5 m brightness temperature in the regions about 10° distant from the galactic equator on the southern side (except around large H II regions) is smaller than that at an equal distance north of the equator. Between latitude +10° and the limit of the survey at about +13° the measured brightness temperature never falls to 1500 °K, whereas much of the zone between −10 and −13° is near 1250 °K. Further from the galactic plane, at −20 to −25°, the brightness temperature is uniform over large tracts of sky at 1100 °K—little more than the values of about 900° observed at this wavelength in the coldest parts of the sky.

(*c*) *Discrete Sources*

The 77 sources in the 3·5 m list show no peculiarities of distribution. The density in the vicinity of latitudes −10 to −15° is rather greater than the average for the whole region surveyed of 0·10 source per square degree, but the difference does not seem to be significant. Many of the objects may be extragalactic.

A comparison of detailed surveys at different wavelengths made with similar instruments has seldom been possible hitherto, and so it is worth considering together Tables 1 and 2. The number of coincidences within 1° is nine, whilst about four would be expected to occur by chance. Very strong sources such as Puppis-A, Vela-X, and Vela-Y are certainly observed at both wavelengths.

Only four of the other sources seem to have been reported by previous observers (see Table 1 for details). Optical identifications seem to be out of the question for the vast majority of the sources ; only three close coincidences between Table 1 sources and NGC or IC objects have been noted. The optical objects concerned—NGC 2220, 2477, and 2547—are star clusters and there is no apparent reason why they should be radio emitters.

The source designated R 54 and R 105 is the well-known Puppis-A (IAU 08S4A), identified with a peculiar galactic nebulosity and probably rather similar to the source Cassiopeia-A. A detailed study of the source at 3·5 m wavelength has been made by Sheridan (1958), and the flux density quoted in Table 1, which is the author's estimate, must be regarded as provisional. Values of its flux density at several other wavelengths have been reported, but it is now clear that most of the observations were subject to confusion with the other intense sources nearby. It is therefore profitless to derive a detailed spectrum from existing data. Qualitatively, however, it appears that at the higher frequencies the flux density increases with wavelength, but there is little change between 3·5 and 15 m. How much of this flattening is due to absorption in interstellar H II regions is not known.

Another interesting source is Vela-X (R 56, R 107), the brightest 3·5 m object. Making an approximate allowance for the width of the aerial beam, the angular size of the source to half-brightness is about $1\frac{3}{4}°$ in Right Ascension and about $1\frac{1}{4}°$ in declination. Gum (personal communication) has suggested its identification with Stromlo 16, an unusual filamentary nebulosity reported by Melotte (1926). However, the nebula is about 4 by 2° in angular size, larger than the 3·5 m source, and the most prominent filaments lie at 230°, −2°, where the radio emission is comparatively weak. The total 3·5 m flux density is greater than that of IC 443, but the latter is brighter optically than Stromlo 16 and appears to show a correlation between optical and radio features (Rishbeth 1956). Thus the suggested identification of Vela-X remains uncertain.

The extended source in Vela-Puppis observed at 75 cm wavelength by McGee, Slee, and Stanley (1955), and at 50 cm by Piddington and Trent (1956*a*), is a blend of Vela-X, -Y, -Z and galactic background. However, more detailed analysis suggests that at these wavelengths Vela-X is the outstanding object in this vicinity, and indicates further that the spectrum of this source may be almost flat in the range of wavelengths for which data are available.

By far the strongest source away from the equatorial belt is R 8, with an integrated flux density of 150×10^{-26} m.k.s. units, or almost 200×10^{-26} units if combined with the weaker source R 6 nearby. Optical identification of such a prominent and isolated feature might be possible, but would perhaps be hindered by the proximity of the star Canopus.

V. Conclusion

It has been shown that the principal H II regions in Vela-Puppis can be detected in emission at 3·5 m wavelength and in absorption at 15 m, and that qualitatively the observed radiation corresponds to the expected thermal emission of these objects. No real evidence for non-thermal emission from H II regions is found. Quantitatively, there is a discrepancy in the sense that the radio emission is too weak. This may well be due to selection of the optical data or other effects arising from non-uniformity of the H II regions; all the objects considered are very faint by optical standards.

The most prominent radio sources in the Vela-Puppis region are located near the galactic plane. They are non-thermal, and are a few degrees in diameter. The variation of radio emission along the galactic equator may be related to the spiral structure of the Galaxy. Many other discrete sources have been located, but their distribution shows no significant departure from uniformity.

VI. Acknowledgments

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Appendix I

Table 1

RADIO SOURCES OBSERVED AT 3·5 M WAVELENGTH IN THE VELA-PUPPIS REGION

No.	Galactic Ref.	R.A. (1950) h m	South Dec. (1950) ° ′	Peak Temp. ΔT_a (°K)	Flux Density S (10^{-26} m.k.s.)	Notes*
R 1	213—25	05 59·5	39 30	300	—	Ridge 3°
R 2	225—27	06 06·0	50 00	275	—	Ext.
R 3	222—25	06 12·3	47 20	450	28	(Puppis-A, Pictor-A)
R 4	212—21	06 17·7	37 05	400	24	
R 5	220—23	06 19·8	45 00	275	17	(Fornax-A) (NGC 2220)
R 6	228—25	06 20·4	52 40	700	44	Part of R 8 ?
R 7	211—19	06 25·1	35 25	450	28	S06–3
R 8	229—24	06 25·3	53 38	2150	*150*	S06–5
R 9	216—20	06 30	40	150	—	Ridge 3°
R 10	212—18	06 31·0	36 40	300	—	Ext.
R 11	227—22	06 38·0	51 00	225	14	
R 12	213—16	06 41·0	36 10	175	11	
R 13	217—17	06 46·4	39 45	575	34	
R 14	233—22	06 50·0	56 00	150	10	
R 15	217—15	06 56·0	39 30	175	11	
R 16	225—17	07 00·9	47 15	300	19	(Fornax-A, Pictor-A)
R 17	223—16	07 02·2	45 30	275	—	Ext.
R 18	221—15	07 04·3	42 45	300	19	
R 19	228—18	07 05·2	50 20	275	17	

* BSS: Bolton, Stanley, and Slee (1954); P: Piddington and Trent (1956*a*); S: Shain and Higgins (1954); Str: Gum (1955).

TABLE 1 (*Continued*)

No.	Galactic Ref.	R.A. (1950) h m	South Dec. ° ′	Peak Temp. ΔT_a (°K)	Flux Density S (10^{-26} m.k.s.)	Notes*
R 20	218—13	07 06	40	300	—	Ridge 2°
R 21	215—11	07 07·2	35 45	300	18	
R 22	231—18	07 08·0	53 00	150	—	Ext.
R 23	230—17	07 10·5	51 30	125	8	
R 24	216—10	07 16	36 30	350	—	Ridge 2° : BSS 103
R 25	220—12	07 16·0	40 50	250	15	
R 26	234—18	07 18·6	55 30	300	19	
R 27	215—09	07 19·0	35 00	150	10	
R 28	232—16	07 20·3	52 50	350	—	Ext.
R 29	220—11	07 21·8	40 00	250	15	
R 30	216—08	07 26·0	35 40	300	18	
R 31	232—15	07 29·3	52 40	300	19	
R 32	216—06	07 32·0	34 40	150	10	
R 33	229—13	07 35·3	49 00	250	15	(Pictor-A)
R 34	219—06	07 38	37	250	—	Ridge 4°
R 35	234—15	07 40	54 30	150	—	Ext.
R 36	234—14	07 41·0	53 20	200	12	
R 37	229—10	07 46·0	47 50	125	8	
R 38	223—07	07 48·0	40 40	250	—	Ext.
R 39	226—08	07 48·1	43 58	550	33	
R 40	227—09	07 48·5	45 30	225	14	(Vela-X)
R 41	221—05	07 49	38 30	250	—	Ridge 3° (NGC 2477)
R 42	218—03	07 50·0	35 00	225	—	Ext.
R 43	225—07	07 51·2	43 00	250	15	(Puppis-A)
R 44	231—10	07 53·0	49 30	250	—	Ext.
R 45	237—14	07 54·0	56 10	150	10	
R 46	236—13	07 56·0	55 00	150	10	
R 47	230—08	07 59·5	47 20	225	14	
R 48	223—02	08 08·0	39 00	500	—	Ext.
R 49	232—08	08 09·4	49 30	600	38	(NGC 2547)
R 50	227—04	08 09·8	42 40	275	17	(Puppis-A)
R 51	222—00	08 12	36	250	—	Ext.
R 52	236—10	08 13	54	250	—	Ext.
R 53	230—06	08 13·5	46 40	325	20	
R 54	228—03	08 21·2	42 50	7000	*750*	08S4A, Puppis-A
R 55	227—00	08 26·0	40 20	300	—	Ext.
R 56	232—02	08 33·8	45 30	5600	*1600*	Vela-X
R 57	228+02	08 41·0	39 45	250	15	Str 14
R 58	231+00	08 42·5	43 30	2500	—	Vela-Y. Ext.
R 59	233—01	08 47·0	45 30	2500	—	Vela-Z. Ext.
R 60	225+07	08 49·0	34 40	225	14	
R 61	236—00	08 58·0	47 20	600	—	Ext.
R 62	233+02	08 59·3	43 20	300	19	(Str 20 ?)
R 63	227+08	09 00	35 30	400	—	Ext.—part R 64 ?

* BSS : Bolton, Stanley, and Slee (1954) ; P : Piddington and Trent (1956*a*) ; S : Shain and Higgins (1954) ; Str : Gum (1955).

TABLE 1 (*Continued*)

No.	Galactic Ref.	R.A. (1950) h m	South Dec. ° ′	Peak Temp. ΔT_a (°K)	Flux Density S (10^{-26} m.k.s.)	Notes*
R 64	230+06	09 01	38 30	600	—	Ridge : BSS 119, P 17 ?
R 65	238—00	09 10	49 20	1200	—	Ext.
R 66	239—01	09 12	50 10	1000	—	Ext.—part R 65 ?
R 67	243—03	09 16·9	54 45	650	42	(Hya-A, Centaurus-A)
R 68	235+06	09 23·3	42 00	225	14	
R 69	241+01	09 25·8	50 20	275	17	
R 70	238+05	09 28·5	45 20	150	10	
R 71	241+02	09 34·0	49 10	250	15	
R 72	239+05	09 35·5	45 30	175	11	
R 73	235+10	09 38	39	150	—	Ridge 2°
R 74	243+02	09 42	50	350	—	Ext.
R 75	239+09	09 46·5	42 20	250	15	
R 76	236+12	09 48	38	275	—	Ridge 3° Str 12b
R 77	242+06	09 49·0	46 50	250	—	Ext.

* BBS : Bolton, Stanley, and Slee (1954); P : Piddington and Trent (1956*a*) ; S : Shain and Higgins (1954) ; Str . Gum (1955).

TABLE 2

RADIO SOURCES OBSERVED AT 15·2 M WAVELENGTH

No.	Galactic Ref.	R.A. (1950) h m	South Dec. ° ′	Peak Temp. (10^3 °K)	Flux Density (10^{-26} m.k.s.)	Notes*
R 100	227—12	07 31	47 00	—30	—	Part of Str 12a
R 101	225—11	07 33	45 00	40	320	
R 102	221—08	07 40	40	45	—	Complex (R 34)
R 103	231—11	07 50	49 30	25	200	(R 44)
R 104	230—07	08 08	47	—40	—	Ext.—Str 12a
R 105	228—03	08 21	43 00	100	800	08S4A, Puppis-A
R 106	235—04	08 37	49 30	30	240	
R 107	232—02	08 38	45 30	45	360	Vela-X (R 56)
R 108	231—00	08 44	44 00	~75	~600	Vela-Y+Z (R 58+R 59)
R 109	231+02	08 50	42 00	—30	—	Str 17
R 110	239—02	09 03	51	40	320	Ext.
R 111	237+00	09 08	48	—35	—	Trough 4° (R 65)
R 112	237+04	09 22	45 30	30	240	
R 113	243+00	09 33	52	55	440	Ext. (R 69)
R 114	236+10	09 38	40 00	—25	—	(R 73)
R 115	242+06	09 54	47	45	360	Ext. (R 77)

* Str : Gum (1955).